# Advanced Alerting Features: Displaying New Relevant Data and Retracting Alerts

Gilad J. Kuperman, MD, PhD, Frederick L. Hiltz, PhD, Jonathan M. Teich, MD, PhD
Department of Information Systems, Partners Healthcare System, Boston, MA

*We added two advanced features to our automated alerting system. The first feature identifies and displays, at the time an alert is reviewed, relevant data filed between the login time of a specimen leading to an alerting result and the time the alert is reviewed. Relevant data is defined as data of the same kind as generated the alert. The other feature retracts alerts when the alerting value is edited and no longer satisfies the alerting criteria. We evaluated the two features for a 14-week period (new relevant data) and a 6-week period (retraction). Of a total of 1104 alerts in the 14-week evaluation, 286 (25.9%) had new relevant data displayed at alert review time. Of the 286, 75.2% were due to additions of comments to the original piece of alerting data; 24.1% were due to new or pending laboratory results of the same type that generated the alert. Two alerts (out of 490) were retracted in a 6 week period. We conclude that in our system, new clinically relevant data is often added between the time of specimen login and the time that an alerting result from that specimen is reviewed. Retractions occur rarely but are important to detect and communicate.*

## INTRODUCTION

Clinicians integrate data to make decisions about patient care. It has long been recognized that certain results should be considered "critical" and need to be communicated immediately to the clinician[1]. For laboratory data, health care institutions are required to have special procedures in place to report critical results to a responsible party[2,3,4]. Recently, automated alerting systems have been developed that can detect a wide variety of clinical conditions and have the potential to replace or complement manual special reporting procedures[5,6,7,8]. To assist physician decision making optimally, alerting systems require features in addition to simply detecting and informing clinicians about serious clinical situations. For this project, we identified and addressed two additional automated alerting system requirements.

New relevant data: The first requirement stems from the fact that certain alerts (known as asynchronous alerts), are generated at the time that data are filed into the patient database by background processes (e.g., batch filing of laboratory results). Asynchronous alerts must be communicated (via page, e-mail, or some other means) to a responsible clinician. The clinician then reviews the alert. Because a time lag exists between the time that a specimen is logged in and the time that an alert resulting from that specimen is reviewed, it is possible that new data relevant to the alerting situation might have become available since the specimen was logged in. For example, if a specimen yields a hypokalemia alert for a potassium result of 2.0 meq/L and by the time the clinician reviews the alert, a new result of 4.3 meq/L has become available for the patient, the clinician should be informed of the new result as well. We refer to such data as *new relevant data*.

Retracting alerts: The second additional requirement stems from the fact that, occasionally, erroneous data enter the database and are corrected subsequently. For example, a technician may transpose digits and enter a hematocrit value of 14g/dL instead of 41g/dL. When the mistake is realized, the technician can edit the existing result. Although automated interfaces to laboratory analyzers render data entry errors uncommon, laboratory specimens are occasionally reanalyzed for a variety of reasons and initial results may be edited. It is conceivable that in such circumstances, the original data triggered an alert but the edited results no longer satisfy the alerting criteria. When manual reporting procedures are used, the physician may not yet have been notified by the time the edited data are available. Or, if the physician has been notified, a repeat phone call can be made to inform him or her that the alerting condition no longer holds. Although these events are rare, they are important to communicate so that inappropriate treatment is not started. When automated alerting procedures are used, mechanisms must be in place to

1091—8280/97/$5.00 

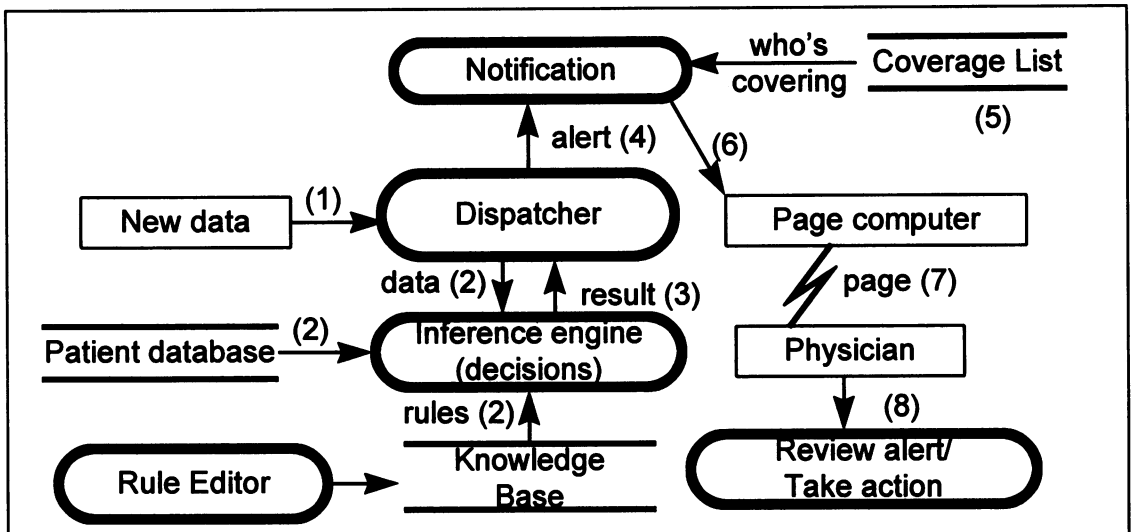


**Figure 1.** Automated alerting system architecture. See text for details.

identify edited data that previously caused an alert, and to retract the alert if necessary.

## BACKGROUND

The features developed for this project were extensions to the automated clinical alerting application in place at Brigham and Women's Hospital.[7] The automated alerting application is part of the Brigham Integrated Computing System (BICS). BICS runs on a network of personal computers and provides financial, administrative, ancillary, and clinical computing services to BWH. Currently there are over 5200 workstations at BWH where clinical data (including automated alerts) can be reviewed. The alerting system generates about 10 alerts per day, two-thirds of which are reviewed by physicians on BICS workstations.

Existing alerting system: The design of the automated alerting application has been described in detail previously[7]. Only a summary will be presented here (Figure 1). As new data enter the system, they are passed to a dispatcher, and then to an inference engine, to determine if any alerting conditions are satisfied. The dispatcher handles queuing. The inference engine uses a knowledge base and the patient database to make its decisions. The knowledge representation used by the inference engine has been described previously.[9] If the inference engine determines that an alerting situation is present, the dispatcher calls a notification function that pages the patient's covering physician.[10] The physician may review the alert on any BICS workstation. If the physician does not review the alert within 15 minutes, the screen border of the workstations on the patient's floor turns red. This informs the nurse that an alert is present and the nurse may then review the alert. If, after 30 more minutes, the alert still has not been reviewed, a workstation in the telecommunications office begins beeping and the telephone operator reviews the alert and calls the patient's floor with the information. The alerting system has not yet replaced the laboratory's manual critical reporting system so some alerts are reported both by the manual system and the automated system.

We decided to add the new relevant data feature in response to a user's suggestion. We added retraction because we will eventually need to mimic our Laboratory's manual procedures.

## SYSTEM DESIGN

The new features were implemented as follows:

Detect and display new relevant data: The alerting system was modified so that when the clinician starts to review an alert, the database is searched for new relevant data filed since the alerting specimen was logged in. Relevant data are defined as the data elements that participated in the evaluation of the rule that led to the alert. For example, if an alert was generated due to a patient having an order for meperidine when their glomerular filtration rate (GFR) was less

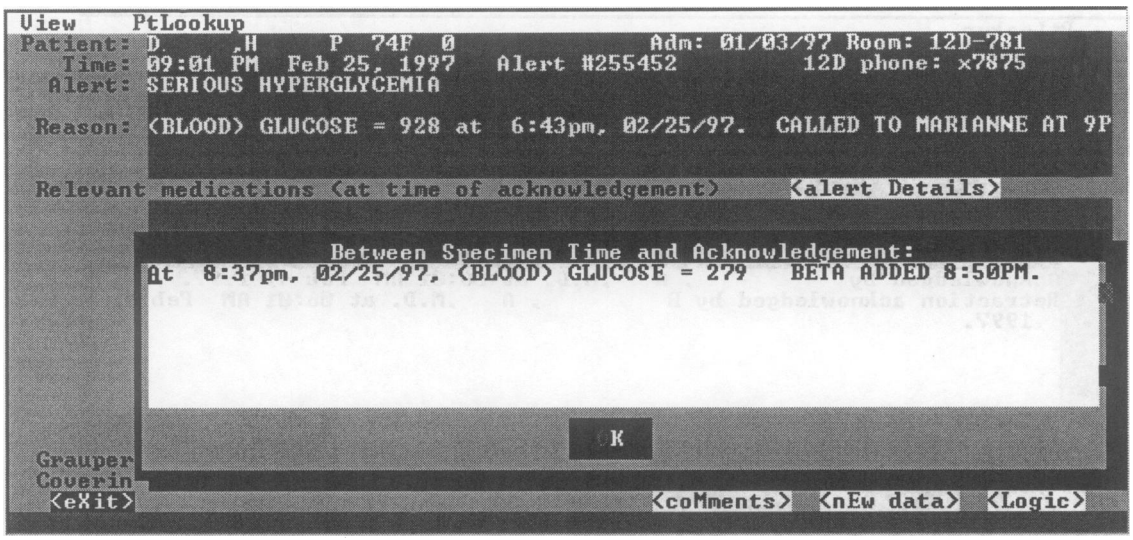


**Figure 2.** Alert review screen showing modal window displaying new relevant data. A specimen logged in at 6:43 p.m. generated a hyperglycemia alert at 9:01 p.m. Before the physician reviewed the alert, a new glucose result of 279 was filed into the database.

than 15 ml/min, then new relevant data at alert review time would be new creatinine results or new or modified orders for meperidine. Because our knowledge representation scheme "exposes" the data fields used to evaluate the rules[9], it is easy to determine which new data in the database are "relevant". In addition to detecting new laboratory results and orders, the new relevant data detection function also identifies edits to the piece of data that triggered the alert (e.g., addition of a comment to a critical laboratory result).

The new relevant data are presented in a modal text box which must be viewed before the primary alert data are reviewed (Figure 2).

Retracting alerts: The retraction function is part of the inference engine. It examines trigger data that have not generated an alert and determines if that piece of data was edited and generated an alert before it was edited. It is possible for the retraction function to make this determination because each piece of data in BICS has a unique identifier. For example, each laboratory result in BICS is uniquely identified by the patient identifier, a specimen number, and a test type. When the inference engine finds that a rule is true and generates an alert, it records in an alert log the unique identifiers of the data elements involved in the alert. If a new laboratory result does not generate an alert (e.g., a hematocrit of 41 g/dL), the retraction function can determine if this had previously generated an alert (e.g., this result was originally 14).

When a retraction occurs, the retraction function amends the alert to include the retraction information. The alert review function then displays the retracted alert. A retracted alert displays all the original alert data as well as a field distinctly indicating that the alert has been retracted and why (Figure 3). If the alert has not yet been reviewed, then the clinician will see the retraction information at the time they first review the alert. If the alert has already been reviewed before the retraction occurs, then notification function will automatically page the physician again. When the physician uses the alert review function, the retracted alert will be displayed.

Interaction between new relevant data and retraction functions: It is possible that a result that caused an alert may be edited but the new result still results in an alert (e.g., hematocrit changed from 14 to 17). In this instance, a retraction does not occur. Rather the new result is displayed via the new relevant data function.

## RESULTS

The new relevant data feature became operational in mid-November, 1996 and the alert retraction feature became operational in mid-January, 1997. For this evaluation, we reviewed

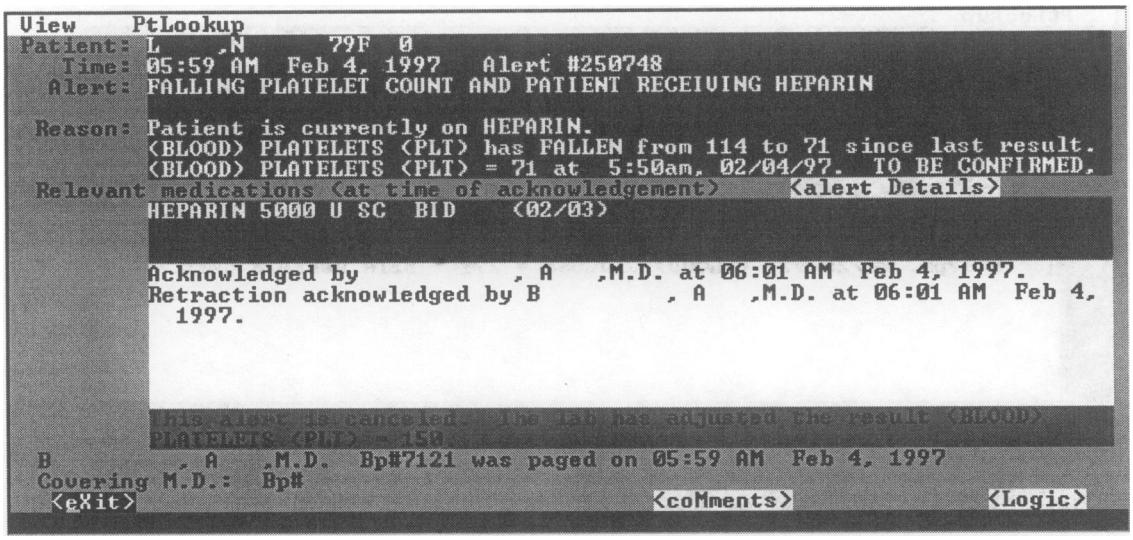


**Figure 3.** Alert review display containing data indicating that alert has been retracted.

all alerts that involved new relevant data and all retracted alerts as of the end of February, 1997 (i.e., a 14-week evaluation period for the new relevant data feature and a 6-week evaluation period for alert retraction).

New relevant data: A total of 1104 alerts were generated in the in the 14-week evaluation period (11.2 per day). Of these, 286 (25.9%) displayed new relevant data at the time that the alert was reviewed. For each of the 286 alerts, the details were reviewed and categorized (Table 1).

**Table 1.** Categories of new relevant data

| Category | N (% of 286) |
|---|---|
| Comments added to original result | 215 (75.2%) |
| "Who was notified" added | 157 (54.9%) |
| More tests ordered on specimen | 29 (10.1%) |
| "Result verified" added | 27 (9.4%) |
| Specimen hemolyzed added | 2 (0.7%) |
| Relevant data from new specimens | 69 (24.1%) |
| Test logged in; results pending | 42 (14.7%) |
| New numeric results since alert | 27 (9.4%) |
| Medication edited | 2 (0.7%) |

The new relevant data was due to comments added to the original alerting laboratory result in 215 (75.2%) of the 286 instances. The categories of comments added to the result included: who on the patient's floor was notified about the panic value (54.9% of 286); the fact that more tests were ordered on the specimen (10.1%); that results were verified (9.4%); and that the specimen was hemolyzed (0.7%). New relevant data involved new laboratory specimens 24.1% of the time. The new data related to new specimens included the fact that new results were pending (14.7% of 286) and that new results had been filed (9.4% of 286). A medication involved in a drug-laboratory interaction had been edited by alert review time in 2 (0.7%) of the instances of new relevant data. The median time until one of the 286 alerts were acknowledged was 30 minutes. In contrast, the median time until acknowledgment for all 1104 alerts was 10 minutes, indicating that alerts that take longer to acknowledge have a greater chance of having new relevant data.

Retracted alerts: A total of 490 alerts were generated in the 6-week evaluation period for retracted alerts. Two alerts (0.4%) were retracted. One retraction was due to a platelet count originally entered as 71,000/mm$^3$, generating a "falling platelets with the patient on heparin" alert. One minute later, the platelet count was changed to 150,000 causing the alert to be retracted. Forty seconds later, the physician reviewed the alert and saw the original data and the data causing the retraction (Figure 3). The other retraction was a hematocrit which was originally entered as 23.3 g/dL and generated a falling hematocrit alert. Thirty minutes later, the result was amended to be 31 causing the alert to be retracted. In this case, no one had yet reviewed the alert and it was removed from the queue of unreviewed alerts.

## LESSONS LEARNED

Approximately one-quarter of all alerts (or, 3 per day) had new relevant data associated with them at the time they were reviewed. Three-quarters of these were due to edits to the original alerting result; one-quarter were due to data from new specimens.

Because informing the clinician about new relevant data distracts their attention (however briefly) from the primary alert data, it is important to determine the clinical significance of the new relevant data. The data related to new specimens (i.e., new or pending data of the same type as the alerting result) are clearly relevant for a clinician reviewing alert data with the goal of making an appropriate decision rapidly. The importance of new relevant data related to edits of the initial result (which were the majority of the occurrences) is less clear. Whereas it would be important to inform the alert reviewer about new data stating that a specimen had been hemolyzed, it may be less important to let them know that the result was "verified" or that new tests were ordered. Because we have not yet replaced our laboratory's manual process for informing the clinicians about critical results with the automated system, information is often present about who on the patient's floor the laboratory notified. Medication order changes are likely important. Therefore, it appears that 6.6% of all alerts (69+2+2/1104) have clinically important new relevant data at the time they are reviewed. For future work, we will try to identify appended comments that are not clinically helpful and refrain from displaying them.

As expected, retractions are rare; however, they do occur and mechanisms to handle them must be present.

## CONCLUSIONS

Important new relevant data is present in 6.6% of alerts at the time they are reviewed. Changes to data requiring the retraction of alerts occurs rarely but is an important event that must be managed. Features such as these are essential if alerting systems are to play a full and active role in facilitating communication in a busy medical setting.


[1] Kost GJ. Critical limits for urgent clinician notification at US medical centers. JAMA 1990;263:704-707.

[2] Commission on Laboratory Accreditation. 1992 Inspection Checklist. College of American Pathologists. Northfield, IL. 1992.

[3] Accreditation Manual for Pathology and Clinical Laboratory services. The Joint Commission for the Accreditation of Healthcare organizations (JCAHO). Chicago, IL. 1994.

[4] Clinical Laboratory Improvement Amendments of 1988. Federal Register. February 28, 1992.

[5] Tate KE, Gardner RM, Weaver LK. A computerized laboratory alerting system. MD Comput 1990;5(7):296-301.

[6] Rind DM, Safran C, Phillips RS, et al. Effect of computer-based alerts on the treatment and outcomes of hospitalized patients. Arch Intern Med 1994;154:1511-1517.

[7] Kuperman GJ, Teich JM, Bates DW, et al. Detecting alerts, notifying physicians, and offering action items: a comprehensive alerting system. Proceedings of 20th AMIA Fall Symposium 1996;20:704-708.

[8] Tate KE, Gardner RM, Scherting K. Nurses, pagers, and patient-specific criteria: three keys to improved critical value reporting. Proceedings of the 19th AMIA Fall Symposium 1995;19:164-168.

[9] Kuperman GJ, Teich JM, Bates DW, et al. Representing hospital events as complex conditionals. Proceedings of the 19th AMIA Fall Symposium 1995;19:137-141.

[10] Hiltz FL, Teich JM. Coverage list: a provider-patient database supporting advanced hospital information services. Proceedings of the 17th AMIA Fall Symposium 1994;17:809-813.